SY22715

Single Stage Buck PFC Regulator For LED Lighting

General Description

SY22715 is a single-stage Buck PFC driver for LED lighting applications.

SY22715 adopts the proprietary control architecture to achieve an accurate regulation of LED current, unity power factor. It drives the converter in Quasi-Resonant mode to achieve high efficiency.

SY22715 integrates 600V MOSFET inside to save driver space further.

SY22715 is available in SO8 package.

Features

- Power Factor >0.9
- 600V MOSFET Integrated
- Quasi-Resonant Operation
- Thermal Fold Back
- Low BOM Cost
- RoHS Compliant and Halogen Free
- Compact Package: SO8

Applications

- LED Lighting

Ordering Information

SY22715□(□□)□
- □ Temperature Code
- □□ Package Code
- □ Optional Spec Code

Ordering Number	Package type	Note
SY22715FAC	SO8	----

Typical Applications

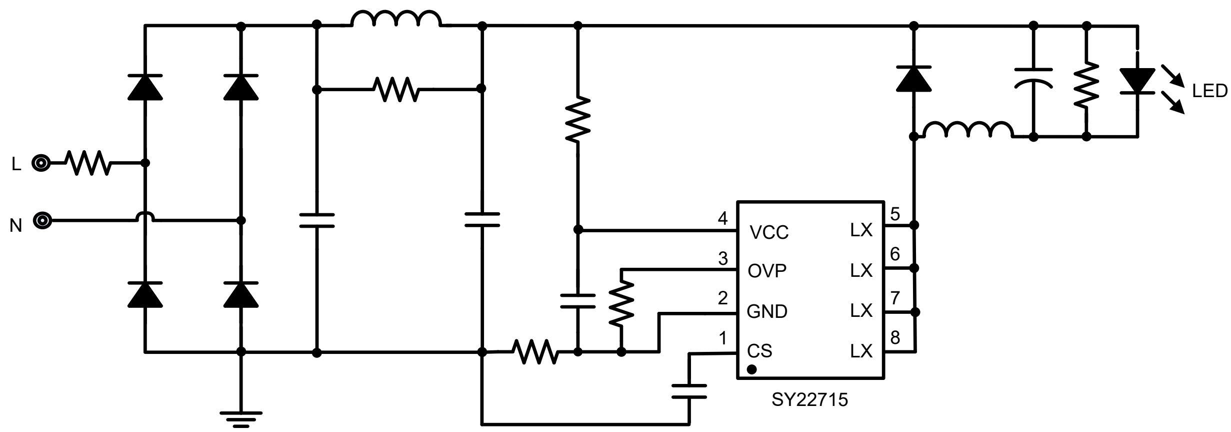
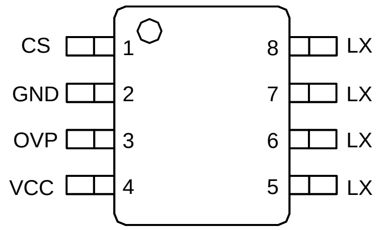


Figure 1. Typical application

Pinout (top view)



(SO8)

Top Mark: CBU*xyz* (device code: CBU, ***x=year code, y=week code, z= lot number code***)

Pin Name	PIN Number	Pin Description
CS	1	Current sense pin, connect a cap and sense res to GND pin. $R_{CS} = \frac{V_{REF}}{2I_O}$
GND	2	Ground pin.
OVP	3	Over voltage protection set pin. Connect a resistor to GND. $V_{OVP}(V) = \frac{K}{T_{OVP}} * \frac{L}{R_{OVP} * R_{CS}}$,K=4400(V· Ω)
VCC	4	Bias supply pin.
LX	5-8	Internal MOSFET drain node.

Block Diagram

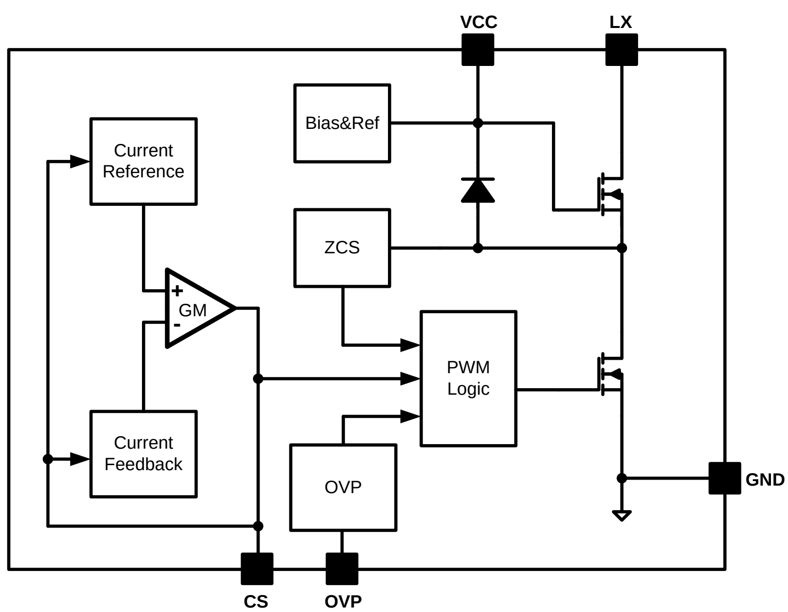


Fig.2 Simplified block diagram

Absolute Maximum Ratings (Note 1)

VCC -- -0.3V~20V
I_{VCC} --- 4mA
CS, OVP -- -0.3V~3.6V
LX -- 600V
Power Dissipation, @ TA = 25°C SO8-- 1.1W
Package Thermal Resistance (Note 2)
SO8, θ_{JA}--- 88°C/W
SO8, θ_{JC}--- 45°C/W
Maximum Junction Temperature --- 165°C
Lead Temperature (Soldering, 10 sec.) --- 260°C
Storage Temperature Range --- -65°C to 165°C

Recommended Operating Conditions

Junction Temperature Range --- -40°C to 125°C

Electrical Characteristics

(VCC = 12V, T_A = 25°C unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Power Supply Section						
VCC Turn-on Threshold	V_{VCC_ON}		13.1	14	14.9	V
VCC Turn-off Threshold	V_{VCC_OFF}		6.8	7.4	8	V
VCC Shunt Voltage	V_{VCC_Shunt}	I_{VCC}=2mA	13.7	14.7	15.7	V
Start up Current	I_{ST}	V_{VCC}=12V	62	70.5	79	μA
Quiescent Current	I_Q		319	352	385	μA
CS Pin Section						
Current Reference	V_{REF}		306	317	328	mV
OVP Pin Section						
OVP Cofficient	T_{OVP}	R_{OVP}=5kohm	9	10	10.9	μs
Driver Section						
Min ON Time	T_{ON_MIN}			780		ns
Max ON Time	T_{ON_MAX}			5.85		μs
Min OFF Time	T_{OFF_MIN}			1.95		μs
Max OFF Time	T_{OFF_MAX}	$V_{CS}\leqslant$50mV		75		μs
Integrated MOSFET Section						
BV of HV MOSFET	V_{BV}		600			V
HV MOS Drain Source Resistance	R_{DSON_H}			2.5	3.1	Ω
Thermal Section						
Thermal Fold Back Temperature	T_{FB}			155		ºC
Thermal Shut Down Temperature	T_{SD}			T_{FB} +5		ºC

Note 1: Stresses beyond the “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note 2: θ_{JA} is measured in the natural convection at T_A = 25°C on a low effective single layer thermal conductivity test board of JEDEC 51-3 thermal measurement standard. Test condition: Device mounted on 2” x 2” FR-4 substrate PCB, 2oz copper, with minimum recommended pad on top layer and thermal vias to bottom layer ground plane

Note 3: The device is not guaranteed to function outside its operating conditions.

Operation

SY22715 is a constant current Buck PFC regulator targeting at LED lighting applications.

It integrates a MOSFET with 600V breakdown voltage to decrease physical volume.

High power factor is achieved by constant on-time operation mode, with which the control scheme and the circuit structure are both simple.

In order to reduce the switching losses and improve EMI performance, Quasi-Resonant switching mode is applied, which means to turn on the power MOSFET at voltage valley;

SY22715 provides reliable protections such as Short Circuit Protection (SCP), Open LED Protection (OLP), and Over Temperature Protection (OTP).

SY22715 is available with SO8

Applications Information

Start up

After AC supply or DC BUS is powered on, the capacitor C_{VCC} across VCC and GND pin is charged up by BUS voltage through a start up resistor R_{ST}. Once V_{VCC} rises up to V_{VCC-ON}, the internal blocks start to work and V_{CS} is pre-charged to certain value.

The whole start up procedure is divided into three sections as shown below. t_{ST1} is the C_{VCC} charged up time. t_{ST2} is the time V_{CS} is charged up to certain value. t_{ST3} is the time IC works at steady state. Usually t_{ST2} is much smaller than t_{ST1}.

If bias supply has more power than IC consumption, V_{VCC} is greater than V_{VCC_Shunt}, and then a shunt current starts to work.

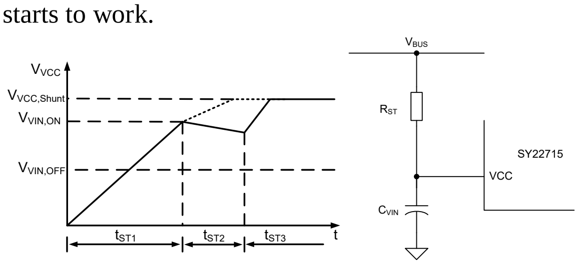


Fig. Start up

The start up resistor R_{ST} and C_{VCC} are designed by rules below:

(**a**) Preset start-up resistor R_{ST}, make sure that the current through R_{ST} is larger than I_{ST}.

$$R_{ST} < \frac{V_{BUS}}{I_{ST}}$$

Where V_{BUS} is the BUS line voltage.

(b) Select C_{VCC} to obtain an ideal start up time t_{ST}, and ensure the output voltage is built up at one time.

$$C_{VCC} = \frac{(\frac{V_{BUS}}{R_{ST}} - I_{ST}) \times t_{ST}}{V_{VCC\_ON}}$$

Shut down

After AC supply or DC BUS is powered off, the energy stored in the BUS capacitor will be discharged. When the power supply for IC is not enough, V_{VCC} will drop down. Once V_{VCC} is below V_{VCC_OFF}, the IC will stop working.

Constant-current control

The output current I_{OUT} can be represented by

$$I_{OUT} = \frac{V_{REF}}{R_{CS} \times 2}$$

Where V_{REF} is the internal reference voltage; R_{CS} is the current sense resistor.

Quasi-Resonant Operation

QR mode operation provides low turn-on switching losses for Buck converter.

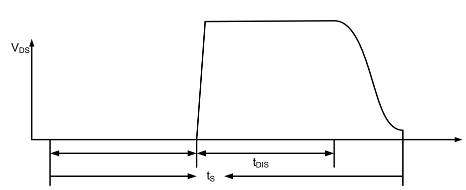


Fig. QR mode operation

When the voltage across drain and source of the MOSFET is at voltage valley, the MOSFET would be turned on.

Open LED Protection (OLP)

The protection voltage V_{OVP} for open LED is set by the resistor R_{OVP} between OVP and GND pin.The relationship is shown as below:

$$V_{OVP}=\frac{K_{OVP}}{T_{OVP}}\times\frac{L_M}{R_{CS}\times R_{OVP}},K=4400(V\times\Omega)$$

If over voltage protection is triggered, the PWM output is stopped and V_{VCC} is discharged. Once V_{VCC} drops down to V_{VCC_OFF}, the IC stops working and then start up again.

Short Circuit Protection (SCP)

If LED is short, bias supply is not enough, and then V_{VCC} is discharged. Once V_{VCC} drops down to V_{VCC_OFF}, the IC stops working, and then starts up again.

Power Device Design

MOSFET and Diode

When the operation condition is with maximum input voltage and full load, the voltage stress of MOSFET and output power diode is maximized;

$$V_{MOS\_DS\_MAX}=\sqrt{2}V_{AC\_MAX}$$
$$V_{D\_R\_MAX}=\sqrt{2}V_{AC\_MAX}$$

Where V_{AC_MAX} is maximum input AC RMS voltage.
When the operation condition is with minimum input voltage and full load, the current stress of MOSFET and power diode is maximized.

Inductor (L)

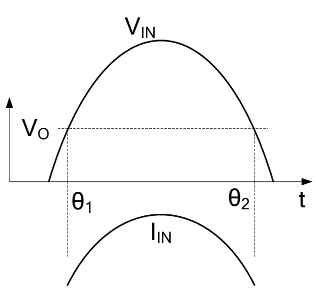


Fig. input waveforms

The power is transferred from AC input to output only when the input voltage is larger than output voltage in Buck converter. The input voltage and inductor current waveforms are shown above, where θ_1 and θ_2 are the time that input voltage is equal to output voltage.

In Quasi-Resonant mode, each switching period cycle t_S consists of three parts: current rising time t_1, current falling time t_2 and quasi-resonant time t_3 shown in below.

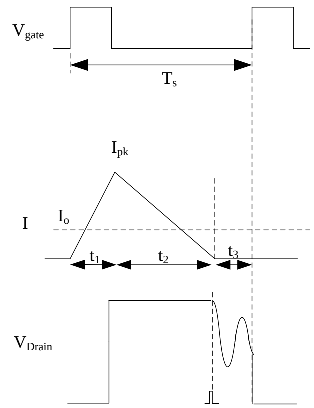


Fig. switching waveforms

The system operates in the constant on time mode to achieve high power factor. The ON time increases with the input AC RMS voltage decreasing and the load increasing. When the operation condition is with minimum input AC RMS voltage and full load, the ON time is maximized. On the other hand, when the input voltage is at the peak value, the OFF time is maximized. Thus, the minimum switching frequency $f_{S\text{-}MIN}$ happens at the peak value of input voltage with minimum input AC RMS voltage and maximum load condition; meanwhile, the maximum peak current through MOSFET and the transformer happens.

Once the minimum frequency $f_{S\text{-}MIN}$ is set, the inductance of the transformer could be calculated. The design flow is shown as below:

(a) Preset minimum frequency $f_{S\text{-}MIN}$

(b) Compute relative t_S, t_1

$$t_S=\frac{1}{f_{S\_MIN}}$$

$$t_1=\frac{t_S\times(V_{OUT}+V_{DF})}{(\sqrt{2}V_{AC\_MIN}+V_{DF})}$$

$$t_2=t_S-t_1$$

Where V_{DF} is the forward voltage of the diode

(c) Design inductance L

$$\theta_1=\arcsin(\frac{V_{OUT}}{\sqrt{2}V_{AC\_MIN}})\times\frac{1}{\pi}\times\frac{1}{2\times f_{AC}}$$

$$\theta_2=\frac{1}{2\times f_{AC}}-\theta_1$$

$$L = \frac{\eta \times f_{AC} \times V_{OUT} \times t_1}{P_{OUT}} \times [\sqrt{2}V_{AC\_MIN} \times \frac{\cos(2\pi f_{AC} \times \theta_1) - \cos(2\pi f_{AC} \times \theta_2)}{2\pi f_{AC}} - V_{OUT}(\theta_2 - \theta_1)]$$

Where η is the efficiency; P_{OUT} is rated full load power;

(d) Compute inductor maximum peak current $I_{L\text{-}PK\text{-}MAX}$.

$$I_{L\_PK\_MAX} = \frac{(\sqrt{2}V_{AC\_MIN} - V_{OUT}) \times t_1}{L}$$

Where $I_{L\text{-}PK\text{-}MAX}$ is maximum inductor peak current;

(e) Compute RMS current of the inductor

$I_{L\_RMS\_MAX}$ is Inductor RMS current of whole AC period

$$I_{L\_RMS\_MAX} = \frac{t_1}{\sqrt{3} \times L}\sqrt{V_{AC\_MIN}{}^2 + V_{OUT}{}^2 - \frac{4\sqrt{2}V_{AC\_MIN} \times V_{OUT}}{\pi}}$$

(f) Compute RMS current of the MOSFET

$$I_{L\_RMS\_MAX} = \sqrt{\frac{t_1}{3t_S}} \times \frac{t_1}{L}\sqrt{V_{AC\_MIN}{}^2 + V_{OUT}{}^2 - \frac{4\sqrt{2}V_{AC\_MIN} \times V_{OUT}}{\pi}}$$

Inductor design (N)

The parameters below are necessary:

Necessary parameters	
Inductance	L
inductor maximum current	$I_{L\_PK\_MAX}$

The design rules are as followed:

(a) Select the magnetic core style, identify the effective area A_e.

(b) Preset the maximum magnetic flux ΔB

ΔB=0.22~0.26T

(c) Compute primary turn N

$$N = \frac{L_M \times I_{L\_PK\_MAX}}{\Delta B \times A_e}$$

(d) Select an appropriate wire diameter with $I_{L\text{-}RMS\text{-}MAX}$, select appropriate wire to make sure the current density ranges from $4A/mm^2$ to $10A/mm^2$.

(e) If the winding area of the core and bobbin is not enough, reselect the core style, go to **(a)** and redesign the transformer until the ideal transformer is achieved.

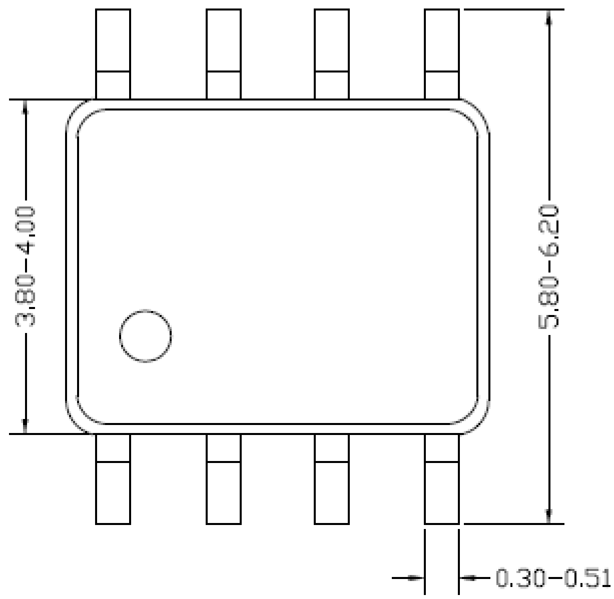
Output capacitor C_{OUT}

Preset the output current ripple ΔI_{OUT}, C_{OUT} is induced by

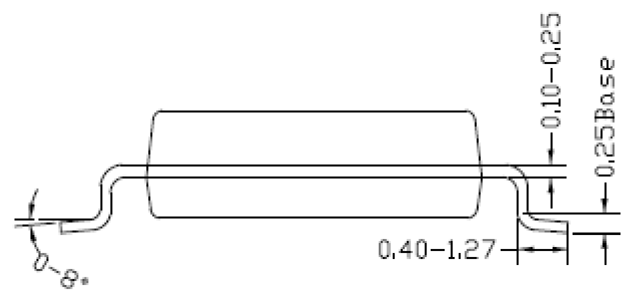
$$C_{OUT} = \frac{\sqrt{(\frac{2I_{OUT}}{\Delta I_{OUT}})^2 - 1}}{4\pi f_{AC} R_{LED}}$$

Where I_{OUT} is the rated output current; ΔI_{OUT} is the demanded current ripple; f_{AC} is the input AC supply frequency; R_{LED} is the equivalent series resistor of the LED load.

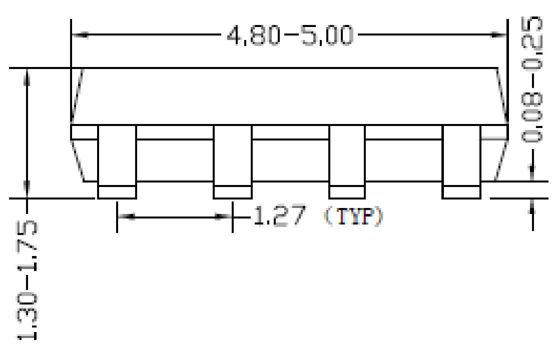
SO8 Package outline & PCB layout design



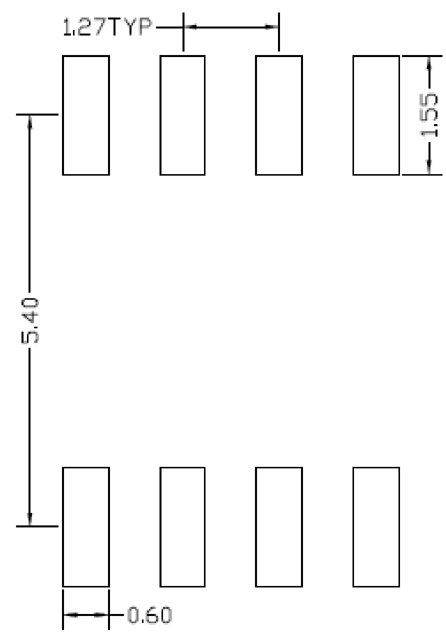
Top view



Side view



Front view

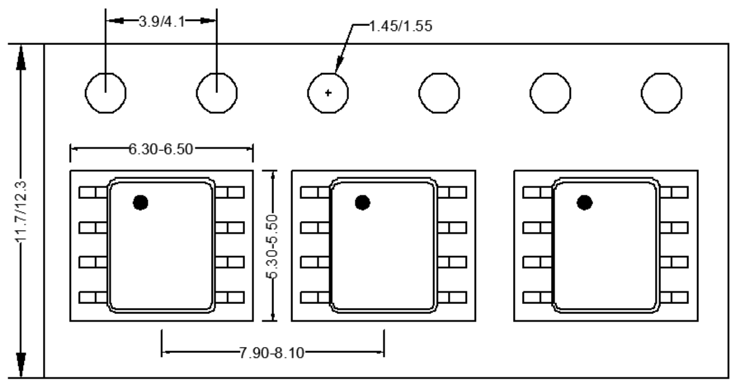


Recommended Pad Layout
(Reference only)

Notes: All dimension in millimeter and exclude mold flash & metal burr.

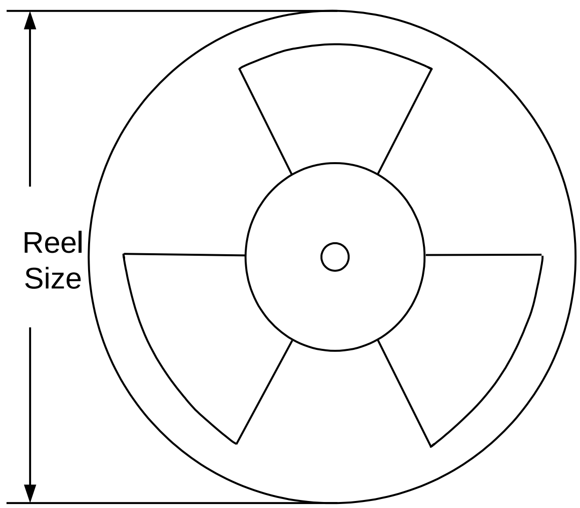
Taping & Reel Specification

1. Taping orientation for packages（SO8）



Feeding direction →

2. Carrier Tape & Reel specification for packages



Package type	Tape width (mm)	Pocket pitch(mm)	Reel size (Inch)	Trailer length(mm)	Leader length (mm)	Qty per reel
SO8	12	8	13"	400	400	2500

Revision History

The revision history provided is for informational purpose only and is believed to be accurate, however, not warranted. Please make sure that you have the latest revision.

Date	Revision	Change
June 11, 2019	Revision 0.9	Initial Release

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